Doubler Requirements for Proton Antiproton Collisions

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I.   Antiproton Collision Schemes in the Energy Doubler

In discussing $\bar{p}p$ collision schemes in the Energy Doubler, we will make several assumptions about the performance of the proton beam. Following this, the performance of the collision system will depend primarily upon the performance and configuration of the antiproton collection system, as well as the performance of the present accelerator systems.

We will assume that the present proton beam intensity in the main ring of 2×10^{13} can be debunched at the Doubler Injection Energy and that about 10% of the beam can be recaptured into 21 bunches of about 10^{11} protons each. This is most economically done by a 1 MHz cavity which prebunches the beam, part of which is recaptured by the main 53 MHz system in 21 equally separated bunches. 20-30 kV is ample voltage for the 1 MHz system. These proton bunches can then be shifted relative to Doubler buckets and can be injected, one at a time, into appropriate locations in the Doubler. Then the number, and spacing of the proton bunches can be chosen, within the constraints of the Doubler injection systems, to optimize the per-formance of the collision system. These bunches, assuming a dilution factor of two, could be as short as two meters, but requirements of longitudinal stability might lengthen them somewhat. If no appre-ciable emittance dilution occurs in transfer to, and acceleration in, the Doubler, then these bunches will cause a modest 2×10^{-3} tuneshift per crossing for the antiprotons. Collision of a single such proton bunch with a single bunch of 6×10^{9} antiprotons will yield a luminosity of $5\times10^{28}\mathrm{cm}^{-2}\mathrm{sec}^{-1}$.

Development of higher luminosity schemes will primarily use more antiprotons and more bunches. For modest luminosity schemes, in which there is no high momentum precooler or accumulator ring, it is necessary to accelerate the antiprotons in single bunches from the 200 MeV cooling ring through the booster and main ring. For more than about 10^{10} particles per bunch serious deterioration of transmission and beam quality occurs in the booster. Therefore, the luminosity per bunch is limited to about $10^{29} cm^{-2} sec^{-1}$. Optimistic estimates of antiproton collection rates would limit the total number to about $3\text{-}4 \times 10^{10}$ for a reasonable collection time, so there might be 6 bunches of protons and antiprotons, with a total luminosity of $\sim 5 \times 10^{29}$, assuming the interaction β can be reduced to about 1.5 m.

Addition of a high momentum precooling ring or accumulator ring would allow more rapid collection of antiprotons, and also allows the possibility to rebunch at higher momentum, removing the restriction on single bunch intensities imposed by the booster. As an example, if 6×10^{11} antiprotons were collected at 200 MeV in a booster length cooling ring, they could be rebunched at 30 MHz, accelerated through the booster with $\sim 10^{10}$/bunch, reinjected into the precooler and rebunched with 12 bunches. These bunches would be individually extracted, accelerated to Doubler injection energy and placed in proper locations in the Doubler. The luminosity would be in the high 10^{30} range. The bunches in each beam would be separated by about 1 μsec, which is adequate for kicker rise and fall times (~ 0.8 μsec) and desirable for experimental instrumentation. About $\frac{1}{3}$ of the ring would be left vacant to accommodate the abort systems.

At this luminosity, there is almost one interaction per
crossing on the average. Higher luminosity schemes must then
employ more bunches. Since this conflicts with single bunch
kicker rise and fall times it will be necessary to regroup the
larger number of bunches into about $\frac{1}{3}$ the circumference of the
main ring, and to transfer all the bunches of protons or anti-
protons at a single time. This scheme, although not worked out
in detail, is compatible with abort and kicker capabilities.

II. Specific needs for Antiproton Collisions

A. Kicker for Injection

The schemes described above are within the present abilities
of kicker systems. Details are described elsewhere.

B. Low β

Work on low beta has centered on schemes which leave the
50 meter straight section clear for magnets to bring the main ring
and doubler proton beams into collision. It is difficult under these
conditions to achieve interaction β values less than 3-5 m. A
scheme for low β was designed by Guignard* which also compensated
the momentum dispersion, but it was for a previous version of the
doubler lattice, and, in addition had a large tune shift. Further
studies should be carried out to attempt to achieve a β* which
is commensurate with the bunch length (β ~1.7 m).

The correction package for the doubler will be influenced
by the need to compensate for the low β section. The tune shift
caused by the insertion should be minimal and, if possible, the
momentum dispersion should be compensated, so that most retuning
of the doubler lattice for low β can be done locally.

*1977 Aspen Summer Study

C.   Radio Frequency Systems

Although these systems are described elsewhere in detail, the special needs should be emphasized here. In order to achieve 10^{11} protons per bunch, a low frequency system is needed in the Main Ring. In addition, it may be necessary to employ a high frequency "Landau" cavity to maintain the stability of these bunches. In order to reverse accelerate the antiprotons in the main ring, the cavities must be rephased at low level.

The radio frequency system for the doubler should be capable of independent acceleration of protons and antiprotons. This can be achieved by proper cavity spacing, as described elsewhere in the report. It appears possible to perform the necessary steps with 6 cavities, but 10 cavities would be preferable. If high frequency cavities are necessary for the stability of the proton bunches, then two must be employed in order to cancel out the antiproton acceleration from these cavities.

D.   Electrostatic Beam Separators

Measurement of collision parameters and luminosity calibration can be achieved by an electrostatic system which separates the beams at the collision point. This is most easily done by placing deflection plates at quadrature points of betatron phase from the intersection point, as for example, about 7 m from the center of adjacent long straight sections. In order to reduce the interaction rate to about 1% of the undeflected rate (for gaussian profiles), about 20 MV electric field x length product is required at each quadrature point ($\beta \sim 68$ m). If 5 MV/m field can be sustained over the 2 cm aperture, 4 meters of electrode is required. In principle, systems should exist for bunching both the horizontal and vertical directions.